PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY B BIOLOGICAL SCIENCES

# A Contribution to the Study of I., Some of the Decussating Tracts of the Mid- and Inter-Brain, and II., of the Pyramidal System in the Mesencephalon and Bulb

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# VI. *A Contribution to the Study of* I., *Some of the Decussating Tracts of the Mid- and Inter-Brain, and* II., *of the Pyramidal System in the Mesencephalon and Bulb.*

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The material which furnished the subject of this research was obtained from cats in which one hemisphere had been removed, or in which a hemisection had been made in the mesencephalon through the superior corpus quadrigeminum and the third nerve. In a preceding paper I have already detailed the descending paths of degeneration, as shown by the Marchi method.

In the present instance the same method is used to demonstrate certain short tract degenerations in the thalamencephalon and mesencephalon as well as the medullated fibres which leave the degenerate pyramidal system both in these regions and in the bulb.

In a paper 'Ueber die Fasersysteme am Boden des Hirnventrikels,'* Darkschewitsch and Pribytkow drew attention to the anatomy of the fibres in front of the third ventricle, viz., Forel's, Meynert's, and Gudden's commissures; in a second paper, 'Ueber den Faserverlauf in der hintern Commissur,'† Darkschewitsch tried to demonstrate the connexions of the fibres of the posterior commissure.

In the present communication, by using the newer method of demonstrating tract degeneration, some fresh facts have been adduced, which it is hoped will contribute to the knowledge of these tracts.

## Forel's *Decussation.*

This name was given by Darkschewitsch to a system of decussating fibres first described by Forel,‡ which lie immediately in front of the third ventricle and behind Meynert's and Gudden's commissures. It must not be confounded with Forel's "fountain" decussation lower down at the level of the oculomotor nerves, although

* 'Neurolog. Centrbl.,' 1891.
† 'Neurolog. Centrbl.,' 1886.
‡ 'Archiv für Psychiatrie,' vol. 7.

the evidence which I will bring forward tends to show that the tract which I am about to describe is part of this system: I shall therefore, to avoid confusion, term it the *upper decussation of* Forel. Care must also be taken not to confound it with Meynert's commissure.

By a limited section passing through a portion of the thalamencephalon D. and P. succeeded, in the new-born cat, in producing atrophy of one decussating tract. They concluded that the "Forel'sche Kreuzung ist ein vollkommen selbständiges Fasersystem, und hat mit der sogen: Meynert'schen Commissur nichts gemein. Die Fasern der Forel'schen Kreuzung stellen einen Theil desjenigen Fasersystems dar, welches nach vorn (Cerebralwärts) vom rothen Kern der Haube liegt, ventralwärts verläuft, sich unterhalb des 3. Ventrikels kreuzt, hierauf längs der ventralen Fläche des Hirnschenkels zwischen diesem und den Tractus opticus weitergeht und den Nucleus Lenticularis an seiner basalen Seite erreicht."

The following illustrations, figs. 1, 2, and 3, are taken from cats in which a hemisection was made through the mesencephalon, passing through the posterior margin of the superior corpus quadrigeminum and the third nerve of the left side, and extending upwards in one case into the thalamus. They show a well-marked group of large degenerated fibres, which sweep round the third ventricle in front, arising in the thalamic area of the one side, and extending far into the internal capsule of the other. These fibres coincide in many ways with D. and P.'s description of Forel's commissure.

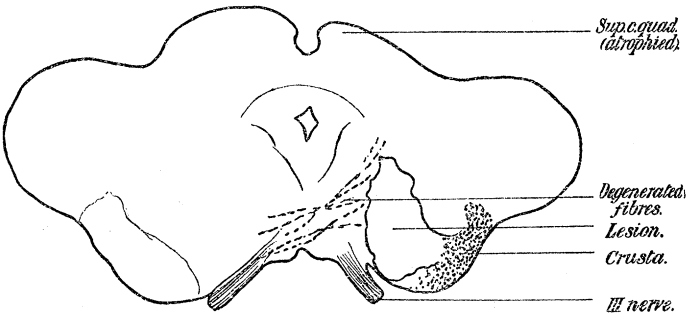
In a section of the mesencephalon in the region of the wound, and through the nuclei of the IIIrd nerve, large fibres pass in a curved sweep from the injured side forward across the IIIrd nerve and raphe, towards the anterior portion of the IIIrd nerve of the opposite side. Having reached the anterior and inner aspect of the red nucleus, the majority of the fibres at this level turn directly downwards, and give origin to the lateral tract of the cord, as described in my first paper.* This crossing I have assumed to represent Forel's fountain decussation. I will now, for reasons given above, term it the *lower decussation of* Forel. The fibres originate in the posterior tegmental gray matter. In a section immediately above the origin of the IIIrd nerves very distinctly degenerate fibres are seen crossing the raphe from the side of the lesion. These fibres are not so numerous or so closely bound together as in the "fountain" decussations of Forel and of Meynert, but their position and their very characteristic large size point to a very close relationship to these decussating systems (fig. 1).

Proceeding upwards through the sub-thalamic area and region of the third ventricle, degenerate fibres can be traced lying scattered in the tegmentum between the superior fillet and the pes pedunculi. At a little higher level, namely, at about that of the anterior third of the thalamus, the fibres bend horizontally and pass forward in a loose bundle between the fornix and the third ventricle. More

* 'Proc. Roy. Soc.,' 1894 (Abstract), see fig. 1.

anteriorly they collect into a well-marked bundle, and sweep round the anterior extremity of the third ventricle. In this position the fibres are readily distinguished from those of MEYNERT'S commissure; they are very large in size, whilst MEYNERT'S fibres are very small. Having passed the ventricle the fibres again diverge slightly, and pass backwards to the neighbourhood of the optic tract lying between it and the

Fig. 1.




Section through the mesencephalon and the centre of the superior corpora quadrigemina to show decussating degenerate fibres, FOREL'S decussation. All figures magnified three times, lesion on left side. Drawn with projection apparatus.

fornix. The degenerate fibres thus lie on the side of the lesion internal to the fornix, whilst on the opposite side they are external. As they proceed backwards the fibres are again grouped closely together, and lie as a compact bundle between the internal capsule (pes pedunculi) and the optic tract. Still further back they arch inwards into the internal capsule, thus avoiding the globus pallidus, and appear to lose themselves in the outer area of the thalamus (fig. 2).

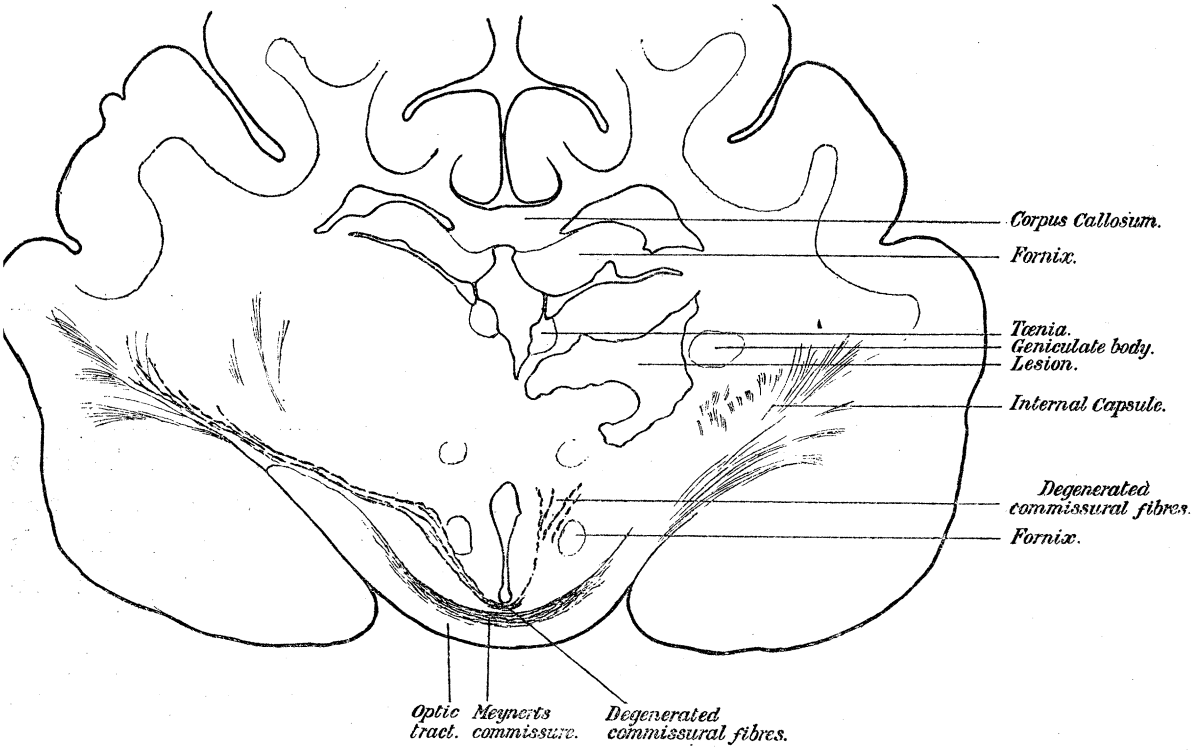
I have not been able to trace the fibres to a more definite ending, and although they at one time appear as if they would continue side by side with the capsular fibres to the cortex, yet careful examination fails to show this.

The description given above coincides in very many details with that given by DARKSCHEWITSCH; the method of MARCHI has, however, enabled me to show that the degeneration proceeds from the tegmental area at the level of the lesion, gradually extends upwards and forwards, curves round to the opposite side, and appears to end in the lateral thalamic region (or possibly cortex), and not in the lenticular nucleus.

The interest of this tract is its undoubted close connexion with the arcuate system of fibres of the lower mesencephalon and probably of the bulbar segments. In my previous paper I drew attention to the relationships of MEYNERT'S and FOREL'S fountain decussations to one another. It was shown that the one formed the antero-lateral column, the other the lateral, there being a gradual transition from the one to the other. MEYNERT'S decussation extended further caudally; FOREL'S, on the other hand, ceased earlier and extended higher up (cerebrally). Both decussations are especially well marked in the lower animals, and both are conspicuous by the

largeness of the medullary sheath, and in consequence by the striking osmic acid reaction of degeneration. The fibres of FOREL'S fountain decussation I could never trace to a definite focus, they arise in the lateral tegmental area on each side of the Sylvian gray matter, and they terminate in the lateral column of the cord. The fibres described above likewise arise in the lateral tegmental area, are of the same size, arch round in front of the continuation of the aqueduct of Sylvius, viz., the third ventricle, and appear to end in the lateral thalamic region. There is no marked

Fig. 2.




Frontal section through the internal capsule and optic chiasma. A lesion is shown on the right side, causing extensive destruction of the thalamus. In the sub-thalamic region large degenerate fibres group themselves into a commissure, which passes in front of the ventricle and proceeds to the opposite side, where it loses itself in the internal capsule close to the cortex.

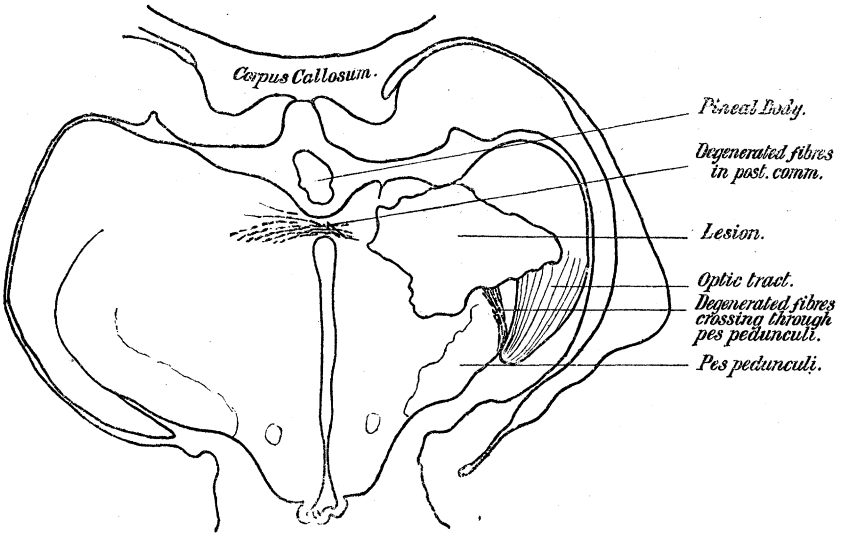
gap between this upper decussation of FOREL and the lower one, scattered degenerate decussating fibres binding the two together. I therefore conclude that these fibres are homologous to the arcuate fibres of lower segments. They take origin at a slightly higher level than the fibres of the lower decussation, but it is a very striking fact that they then gradually *ascend* to their termination. There is, in fact, a fan-shaped system of decussating fibres, which arises in the tegmentum, extending the length of the superior corpus quadrigeminum and lower part of the thalamus; from this basis the fibres spread out slightly upwards and downwards, the latter turning

directly downwards after they have passed out a certain distance. From this region in the mesencephalon the degeneration is centrifugal.

### *Meynert's Commissure.*

This commissure enters into the formation of the schema of the fillet described by BECHTEREW.* He states that the fillet fibres are not only connected with the globus pallidus of the same side, but by means of MEYNERT'S commissure are brought into relationship with that of the opposite side. The latter commissure also serves to bind together the lenticular nucleus and the corpus Luysii; he thinks that DARKSCHEWITSCH and PRIBYTKOW (*l.c.*) have disproved the view that it connects the two corpora geniculata interna. These last authors describe the connexion of the tract

Fig. 3.




Section through the interbrain close to the mesencephalon, and passing through the posterior-commissure. The lesion involves the thalamic region, corpora geniculata, commencement of superior corpus quadrigeminum, and portion of the pes pedunculi. Degenerated fibres are seen in the posterior commissure, and a tract of them crossing the pes pedunculi.

with the stalk of the nucleus lenticularis, there mixing with the fibres which surround the basal surface of the lenticular body. In addition they describe a not inconsiderable bundle of fibres which does not reach the lenticular nucleus, but which arches inwards transversely across the dorsal portion of the pes pedunculi and enters the corpus Luysii. Not all the fibres, however, enter this body, a few passing back dorsally to penetrate the region of the thalamus, to intermingle with the fibres of the upper (median) fillet.

In my own experiments I have succeeded in producing degeneration of a tract

* *Loc. cit.*

(figs. 2 and 3), which may correspond to MEYNERT's; nevertheless, I have found it impossible to come to a definite conclusion as to its complete mode of origin and termination.

Fig. 3 is a section made through the lower caudal portion of the thalamic region, and shows the original wound caused by the hemisection. A group of degenerate fibres arches through the pes pedunculi, springing from the region of the corpus Luysii and the region immediately posterior to it, both of which are involved in the lesion. The degenerate fibres group themselves into a well-marked bundle closely applied to the outer aspect of the pes pedunculi and between it and the optic tract. The fibres then pass anteriorly with the optic tract and cross in front of the 3rd ventricle, as seen in fig. 2. They then turn back and caudally along the inner side of the optic tract. As they descend caudally they appear to diminish in number, and not to enter the corpus Luysii of the sound side; a few of the fibres may penetrate with the optic tract into the thalamic region and intermingle with the superficial fibres of the superior fillet. In the same section, owing to the extension upwards of the wound, the ansa lenticularis was very completely degenerate; notwithstanding this I could trace no actual connexion between these degenerate fibres and MEYNERT's commissure. From an examination of a large number of sections it would appear that MEYNERT's commissure has a wide seat of origin, numerous fibres either passing through, or arching round, the pes pedunculi on its dorsal aspect to form it. The latter fibres may be upper fillet fibres coming from the superior corpus quadrigeminum.

### *The Posterior Commissure.*

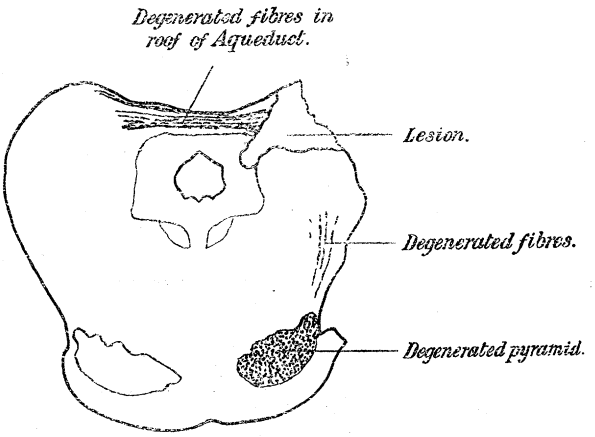
The posterior commissure is usually divided into dorsal and ventral fibres. DARKSCHEWITSCH traces fibres from the ventral portion into the posterior longitudinal bundle and to a close relationship with the root of the third nerve. BECHTEREW states that he finds that in the Mole the fibres of the posterior longitudinal bundle end in the upper oculomotor nucleus, and that in the same animal the ventral portion of the posterior commissure is of considerable size. HELD* figures fibres crossing in the commissure and turning down in the anterior lateral column system of the opposite side. I have had the opportunity of examining this commissure in numerous cases of unilateral lesion extending along the region of the superior corpus quadrigeminum.

In fig. 3 the edge of the wound abuts directly on the posterior commissure and extends for a considerable distance both above and below the commissure. The extent of the lesion downwards is well seen in the next figure (fig. 4), taken through the inferior corpus quadrigeminum. There was no doubt, therefore, that in this case the fibres which entered the commissure from one side were very completely interrupted. An examination of a series of sections shows that the degenerate fibres resulting from the lesion have not a long course. In the first place, the fibres

* HELD, "Die Centrale Gehörleitung," 'Archiv f. Anat. u. Phys.,' 1893.

do not, as a rule, run horizontally across the commissure, but arch obliquely. They are most conspicuous in the ventral portion of the commissure, and a large number of them terminate in the dorsal and opposite lateral aspect of the Sylvian gray matter, a few scattered fibres appear to curve round the gray matter and to extend towards the raphe, but I have not been able in any instance to trace degenerate fibres into the posterior longitudinal bundle. Other fibres radiate into the posterior tegmental area, and the remainder into the corpus quadrigeminum. The fibres which cross, therefore, in the posterior commissure appear to have a short course, they focus in the central and ventral aspect of the commissure and then diverge again, there is thus an interlacement in the commissure. There are few fibres in the dorsal portion of the commissure. When the preceding commissure is compared with that forming the roof of the aqueduct lower down, differences become apparent. Fig. 4 is a section passing through the posterior corpora quadrigemina. It will be

Fig. 4




Section through upper part of pons and inferior corpora quadrigemina, to show degenerated fibres passing back from the pyramid to the quadrigeminal region, also degenerated fibres in the roof of the aqueduct.

seen that the commissural system is much more extensive than higher up, and that the fibres for the most part run straight across and then spread out in the opposite corpus quadrigeminum. There is no ventral concentration of fibres, the commissure being uniform throughout; the fibres are slightly smaller than those in the posterior commissure. I have not succeeded in tracing any around the Sylvian gray matter, the fibres appearing to terminate in the corpus quadrigeminum. In addition to the above system of fibres, there are large medullated fibres, which for the most part lie superficially in the roof, and they appear to terminate in the lower portion of the superior or upper portion of the inferior corpus quadrigeminum. Their origin will be discussed immediately.

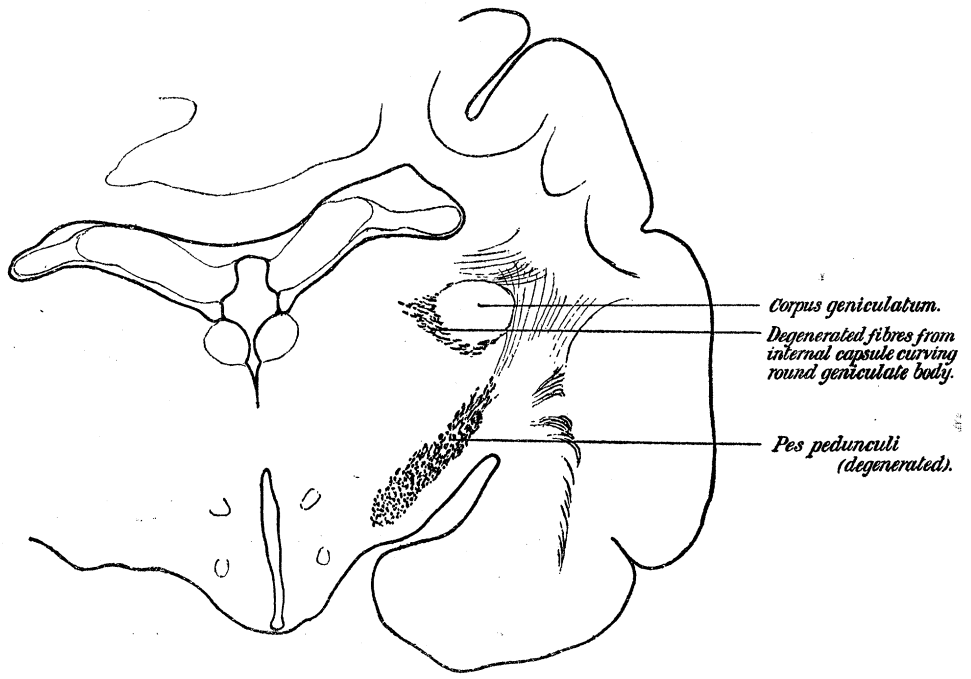
In conclusion, it may be stated that the degenerate fibres, which cross in the commissure or roof of the aqueduct, and which result from a unilateral lesion of the

quadrigeminal area, have not a long course, but terminate for the most part in the opposite corpora quadrigemina, dorsal and lateral aspects of the Sylvian gray matter, or posterior portion of the tegmentum.

*The Dorsal Fibres of the Commissure in the Roof of the Aqueduct of Sylvius.*

I first noticed the degeneration of these fibres in cases where the anterior third of one cerebral hemisphere had been removed, and in which, therefore, there was very complete degeneration of the internal capsule. Sections through the middle region of the thalamus clearly showed a group of scattered large degenerate fibres leaving the internal capsule and entering the optic thalamus. The fibres (fig. 5) pass

Fig. 5.

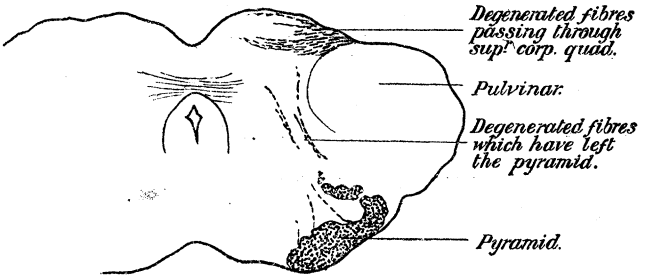



Frontal section through brain, behind level of fig. 2. Cat, anterior $\frac{1}{3}$ of left hemisphere removed.

downwards and inwards; they encircle the median geniculate body, and then turn upwards, passing beneath the fibres going to form the optic tract, as well as the corpora geniculata and pulvinar. They become superficial in the stalk of the superior corpus quadrigeminum, lying in the rear, between the pulvinar and the corpus quadrigeminum (figs. 6, 7). They penetrate the corpus, many of the fibres probably terminating here; others, however, remain or become superficial in the hinder portion of the superior corpus, and cross over to the opposite side in the roof of the aqueduct of Sylvius as the large medullated fibres described above. The fibres are not traceable below the inferior corpus, and they appear to remain confined to the quadrigeminal bodies.

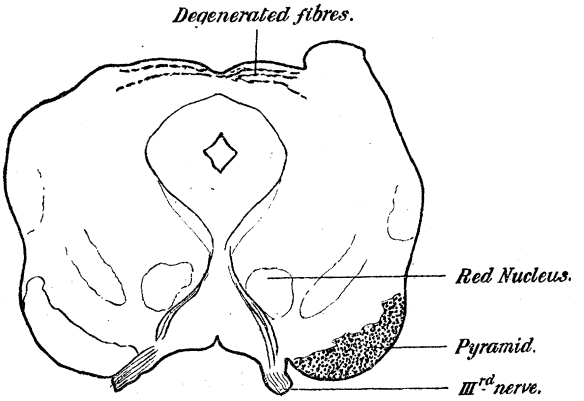
There is not yet sufficient evidence to say whether these fibres are of cortical origin, but appearances would favour the view. The fact remains, however, that a descending tract of fibres leaves the internal capsule, traverses the thalamus, and is distributed to the quadrigeminal region of the opposite, and probably of the same, side. The reason for supposing the fibres to be of cortical origin will appear more clearly in the next section, where it will be shown that fibres leave the pes pedunculi and pass backwards to the quadrigeminal region.

Fig. 6.




Section through mesencephalon above the level of the IIIrd nerve, to show fibres derived from internal capsule and pyramid.

Fig. 7.




Section through mesencephalon, red nuclei and 3rd nerves, to show termination of degenerate fibres which have come from the internal capsule.

## II.—The Pyramidal System in the Mesencephalon and Bulb.

An examination of consecutive series of sections of a large number of cases of pyramidal degeneration in the cat, showed unmistakably that degenerate medullated fibres leave the pyramidal system in the mesencephalon, pons, and medulla. At first, owing to their fewness in number, their presence was regarded as accidental; careful examination, however, revealed them in all cases, and, moreover, in a recent paper Muratoff* has figured them in two situations in the bulbar segments.

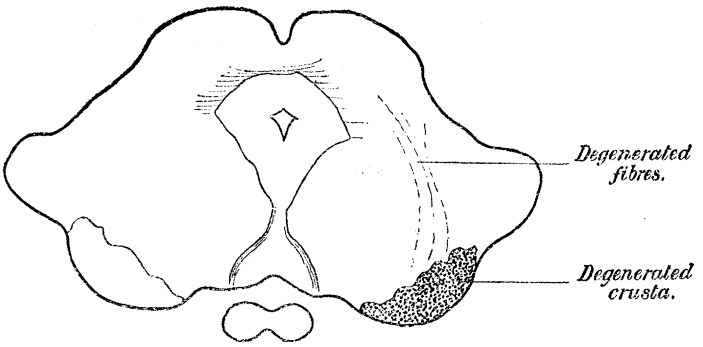
* Muratoff, 'Archiv f. Anat. u. Phys.,' 1893; and recently Rothman, 'Neurologisches Centrlb.,' June, 1896.

The fibres turn horizontally out of the pyramid and pass backwards, usually across the raphe, to the opposite side. They cannot be traced by this method to end in the motor nuclei; all that can be said, is that they lose themselves in the hinder portions of the tegmentum.

*Mesencephalon.*—Small groups of fibres were found to leave the dorsal and inner portion of the pes pedunculi (fig. 6), and to pass backwards to the tegmental, commissural region of the same side, but whether they actually crossed over in the posterior commissure to the opposite side is not proved. In fig. 6 the relationship of these small bundles to the fibres derived from the internal capsule is well seen, and makes it probable that the latter are also of cortical origin.

Fig. 8 shows degenerate fibres leaving the *crusta* further down to pass back to the quadrigeminal region of the same side. These fibres appear to be fairly numerous, and MURATOFF (*l.c.*) has drawn attention to them.

Fig. 8.




Section through mesencephalon at upper limit of IIIrd nerves and superior corpora quadrigemina, to show degenerated fibres leaving the degenerate crusta and passing back to the quadrigeminal region.

*Pons.*—There is every reason for supposing that the pyramidal fibres undergo diminution in this region. Their mode of termination is very obscure, however, and only a few fibres turn horizontally out to cross the raphe, and end in the tegmentum of the opposite side.

*Medulla.*—A considerable number of fibres may be observed leaving the inner angle of the pyramid in the upper portion of the medulla, corresponding to the region of the nucleus of the Vth. The fibres cross the raphe, and end in the tegmentum in the vicinity of the direct lateral columnar fibres.

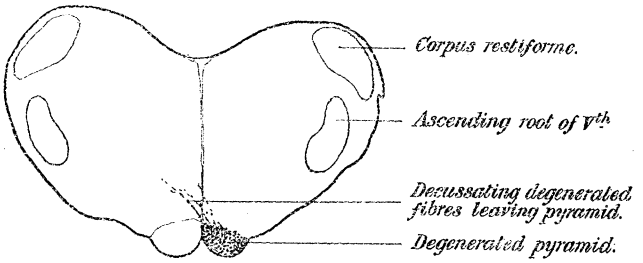
Corresponding to the nuclear areas of the VIth and VIIth nerves, a number of fibres also leave the inner part of the pyramid (fig. 9). Attention has again been directed to them by MURATOFF (*l.c.*), who supposes that they are the cortical motor fibres of the VIIth. I have not observed them terminating in the nucleus, but I have seen them terminating close to the nucleus of the VIth.

Just below the level of the trunk of the VIth nerve fibres may be seen leaving the

inner angle and dorsal aspect of the pyramid, to disappear at the dorsal aspect of the nucleus lateralis of the opposite side.

At levels corresponding to the area of the hypoglossal nucleus, fibres are given off from the inner posterior and inner anterior corners of the pyramid; the latter traverse the sound pyramid of the opposite side. The fibres run backwards and to the opposite side in the bundles of sensory decussating fibres. They appear to end in the tegmental region external to the nucleus of the XIIth.

Fig. 9.




Section through the mid medullary region a little below exit of VIIth.

Still lower down, at the lower end of the medulla, both pyramids sink deeply towards the central canal; previous to decussation, however, numerous fibres cross to the opposite side in the bundle of the sensory decussation, and with the latter fibres they lose themselves in the hinder tegmental region.

It seems very probable that the fibres described above serve to connect the pyramidal system with the motor centres of the quadrigeminal region and bulb. The decussation of the pyramid is thus not confined to the upper cervical region, but, as one would expect, is gradually taking place during the descent of the pyramid through the bulbar segments. As has already been seen, the majority of the fibres decussate; a few, however, and this is notably the case in the quadrigeminal region, appear to remain on the same side. This again accords with the fact that there are also direct and crossed paths to the motor centres of the cord.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